Update on Dependable Multiprocessor (DM) CubeSat Technology

presented at the

2012 Summer CubeSat Workshop/
Small Satellite Conference

August 12, 2012

Dr. John R. Samson, Jr.
Honeywell Aerospace, Defense and Space
Clearwater, FL
john.r.samson@honeywell.com

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Outline

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- **Brief overview of DM technology**
- **Update on DM CubeSat technology development since 2011 Summer CubeSat Workshop**
  - **DM CubeSat Testbed**
  - **SMDC TechSat Flat-Sat Demo (9/11)**
- **Upcoming SMDC TechSat Phase 2 F-Cubed Demo (9/12)**
- **Elicit interest in possible joint DM CubeSat and/or DM small satellite experiments**
- **Summary and Conclusion**

Dependable Multiprocessor (DM) Technology

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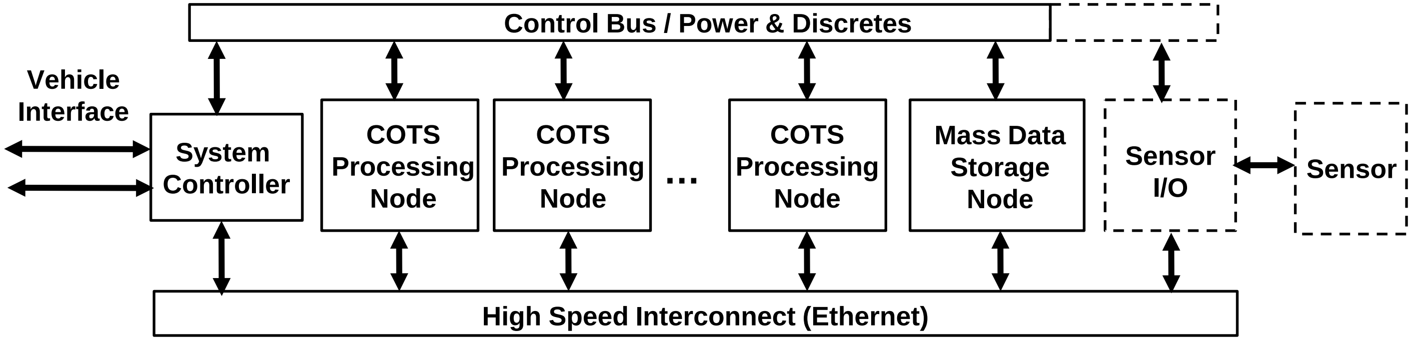
- NASA-developed technology
  - Cluster of high-performance COTS processors
  - Operated under the control of a reliable system controller and technology-, platform-, and application-independent fault tolerant DM Middleware (DMM)
  - Flexible
    - -- user-configurable fault tolerance includes hybrid replication [temporal and spatial self-checking and TMR (Triple Modular Redundancy) for critical functions and ABFT (Algorithm-Based Fault Tolerance)]
  - Scalable
  - Low overhead (<10% throughput & memory)
  - Easy to use
  - Achieved TRL6 in 2009

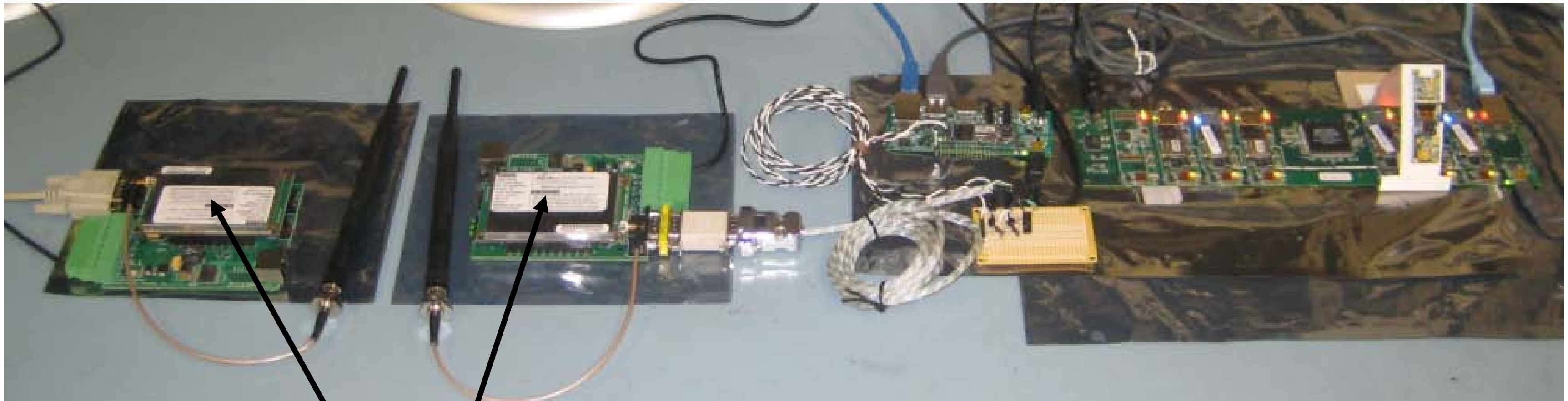
Simple DM Flight Experiment System



The technology-, platform-, & application-independent DM Middleware (DMM) is DM technology; DM technology is not the underlying hardware

DM CubeSat Testbed Photo (1 of 2)

Honeywell



Pumpkin Comm. Modules

DM Payload Processor

Complete, end-to-end, space/ground testbed system including command & telemetry system over an RF link

DM CubeSat Testbed Photo (2 of 2)

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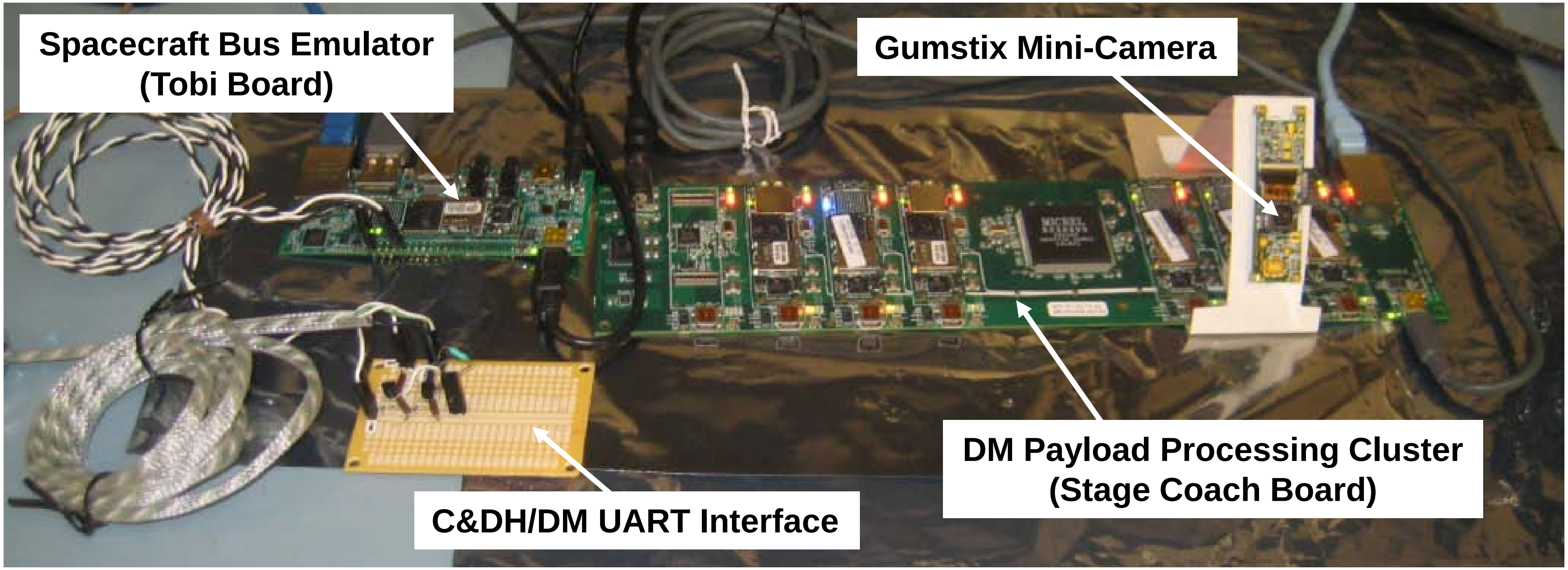

RADIANCE TECHNOLOGIES

SMDC TechSat Flat-Sat Demo (9/11)

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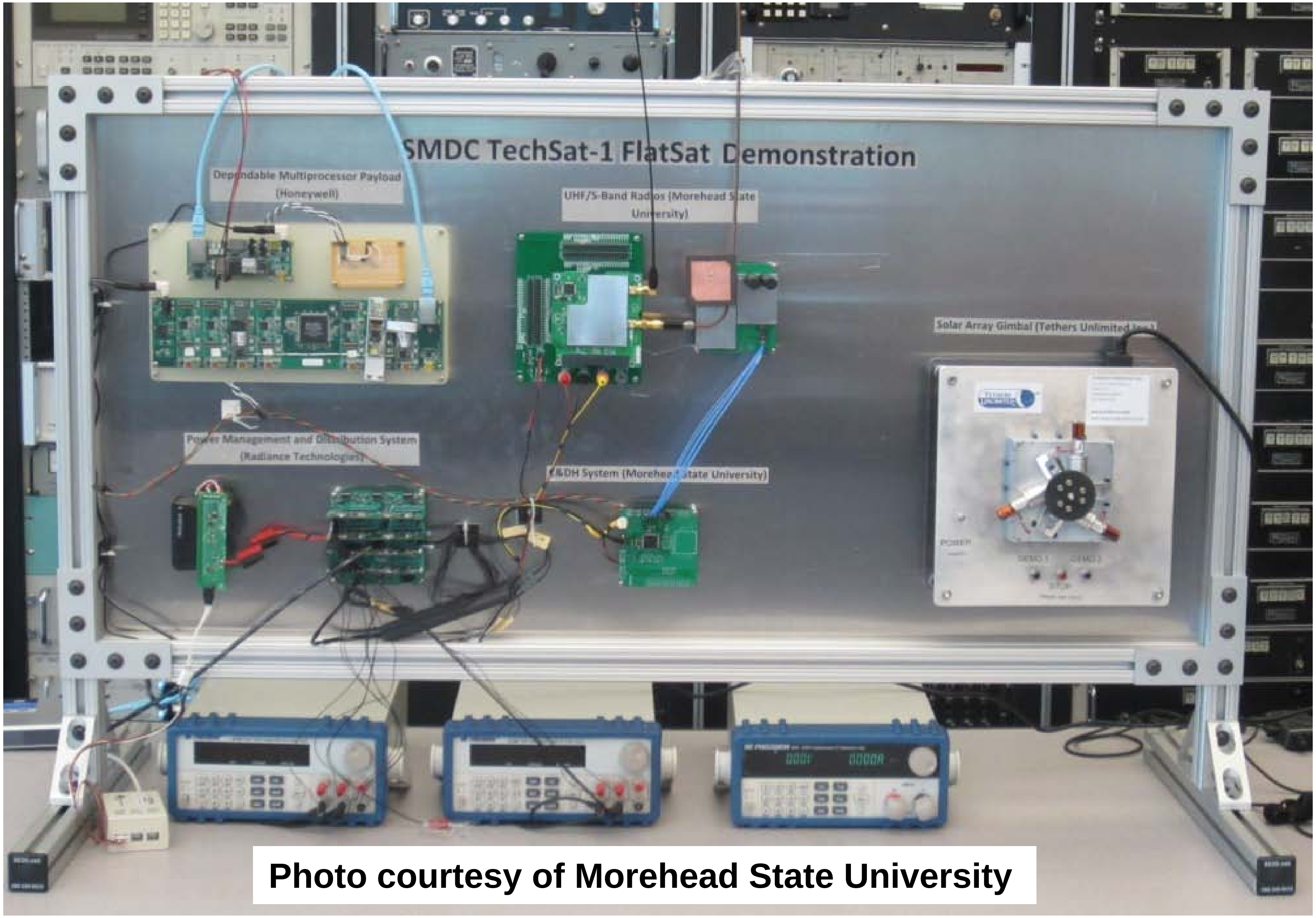
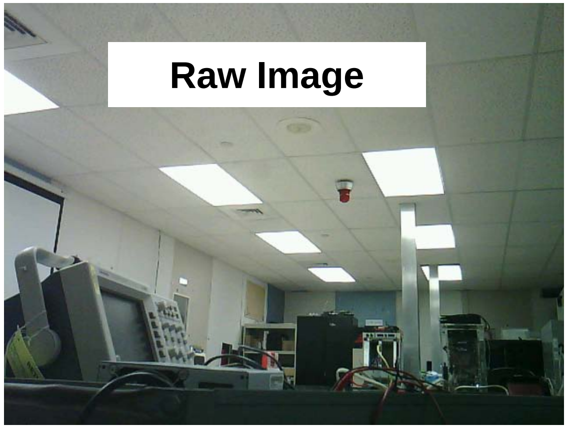


Photo courtesy of Morehead State University

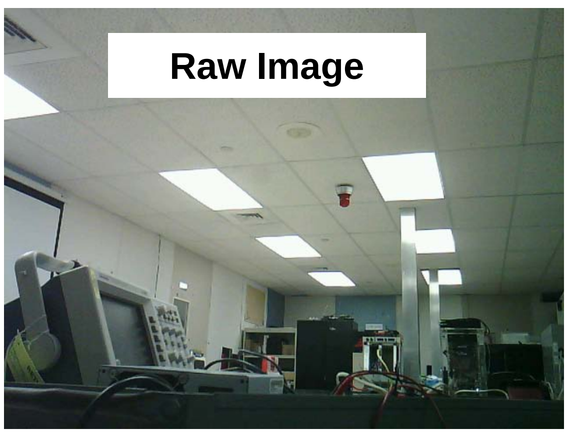
Ground-Commanded Programmable Data Compression – JPEG 2000



Raw Image Size: 921654 Bytes
Frame Time: 15 seconds

Compressed Image Size: 435734 Bytes
Execution Time: 2.449 seconds

Average R error = 0.0 ^
Average G error = 0.0 ^
Average B error = 0.0 ^



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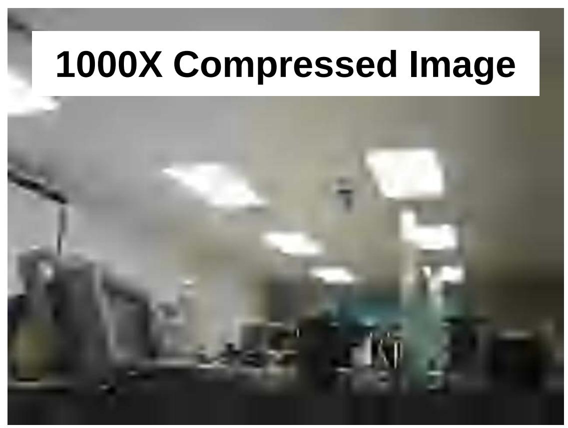

Compressed Image Size: 922 Bytes
Execution Time: 3.041 seconds

Average R error = 11.183 ^
Average G error = 8.626 ^
Average B error = 9.947 ^

* ABS [Raw Image Pixel (x,y) – Compressed Image Pixel (x,y)]
^ Average difference in pixel value over the entire image (8-bit pixel data; range 0 - 255)

SMDC TechSat Flight Experiment Configuration

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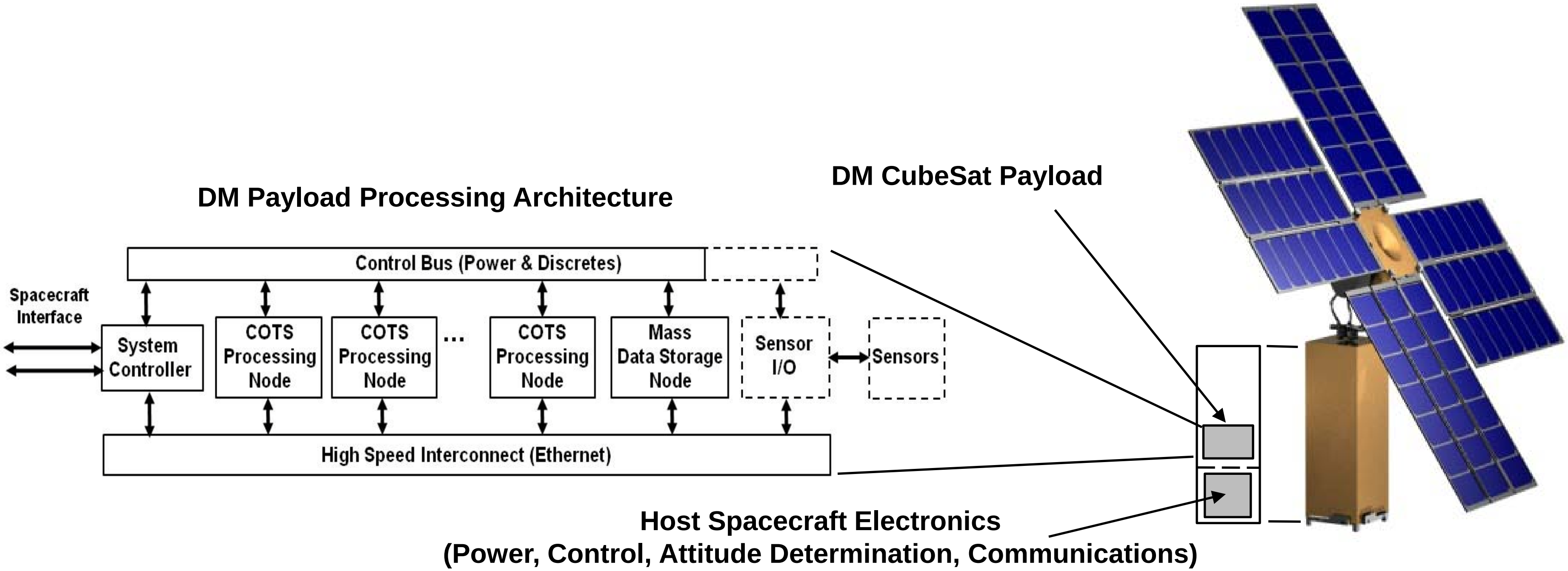
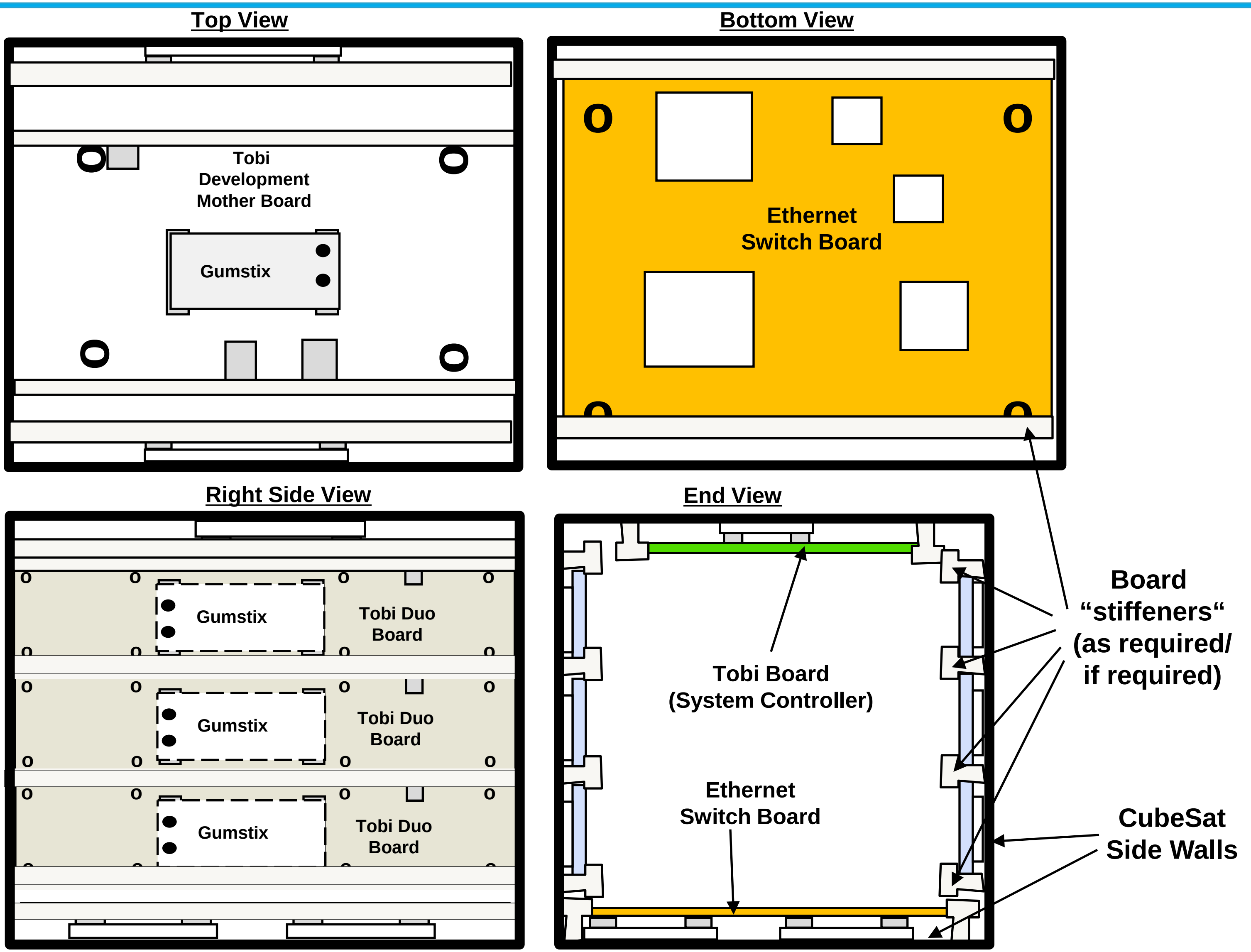


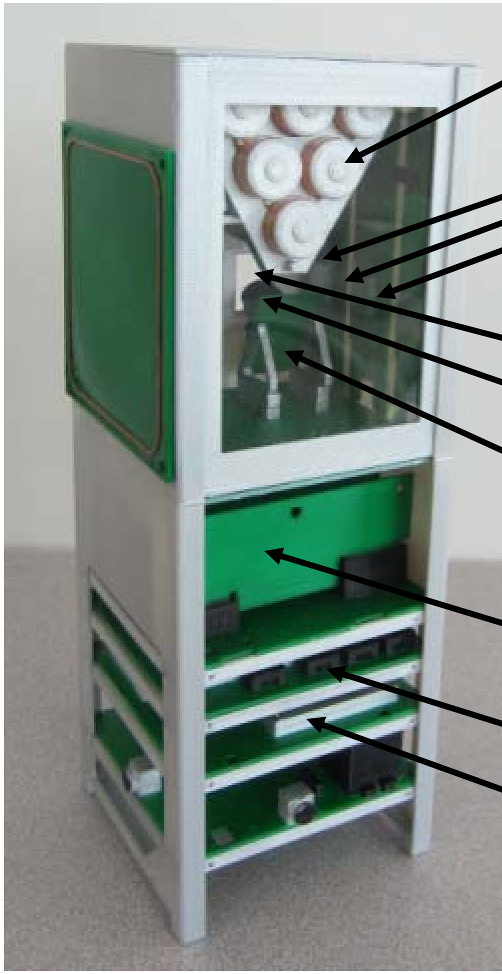
Launch Size:	**10 cm x 10 cm x 34 cm**
Deployed Size:	**78 cm x 78 cm x 44 cm**
Mass:	**6 kg**
Power:	**~ 65 Watts (Peak) (85 Watts goal)**
	~ 40 - 50 Watts (On-Orbit Average)

Original DM Payload Integration & Mounting

Physical configuration verified by MSU 3D CAD and 3D printed models of the SMDC TechSat including DM for the Flat-Sat Demo



Full-Size 3D-Printed Mockup of SMDC TechSat (minus articulated solar array)



Battery pack for pre-solar array deployment start-up & operation during solar eclipse

Six (6) DM Gumstix DP nodes (three (3) on each side)

DM System Controller Board

Camera Portal

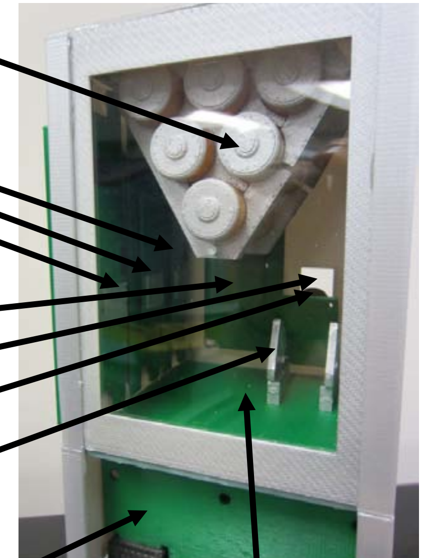
Camera

Camera Mount

Power Management & Distribution (PMAD) Subsystem Boards

C&DH Board

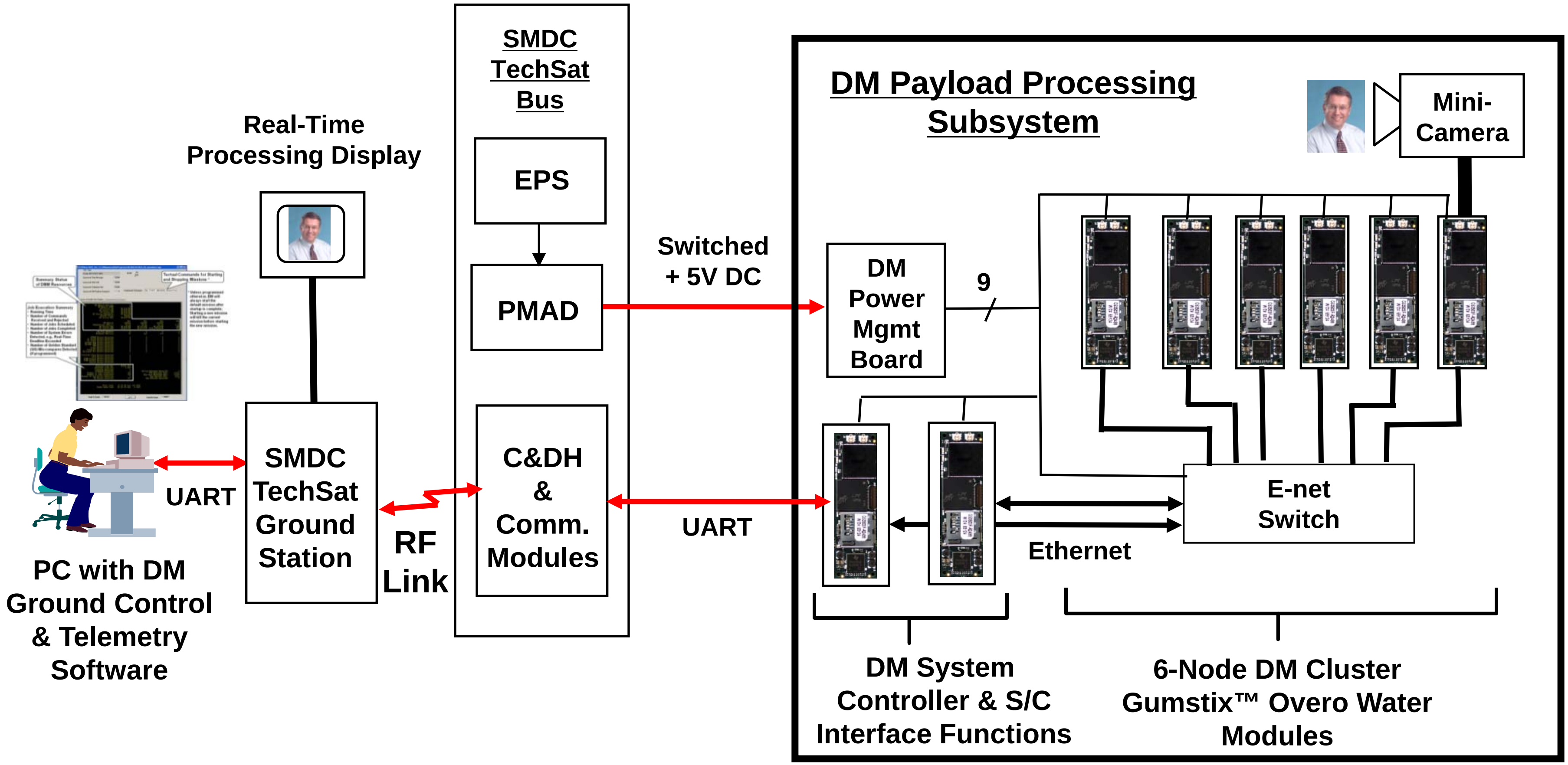
RF Subsystem boards



Plexiglas window to allow visibility inside the CubeSat to see the details of the DM payload processor, camera, and battery pack (the DM Ethernet Switch is mounted on this face of the CubeSat)

Photos courtesy of Morehead State University

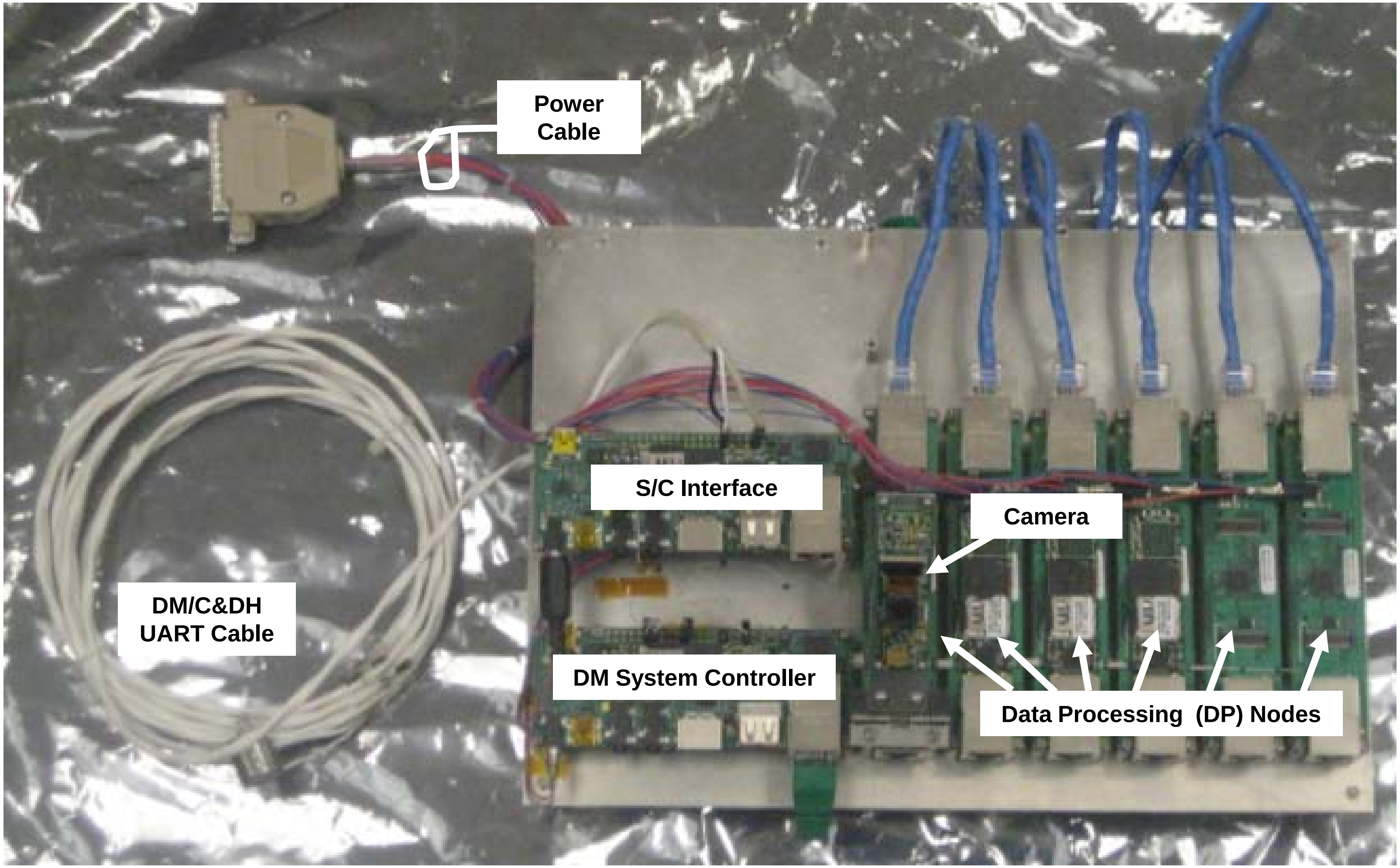
Phase 2 DM Subsystem Flight Configuration



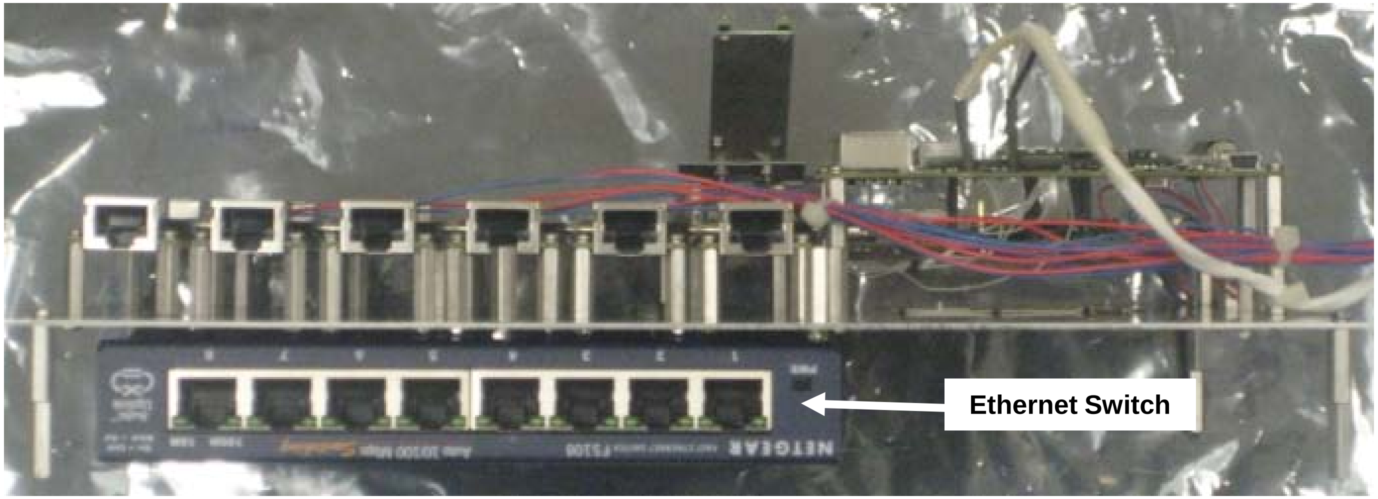
Same DM hardware as Flat-Sat Demo; major change is the form factor for flight

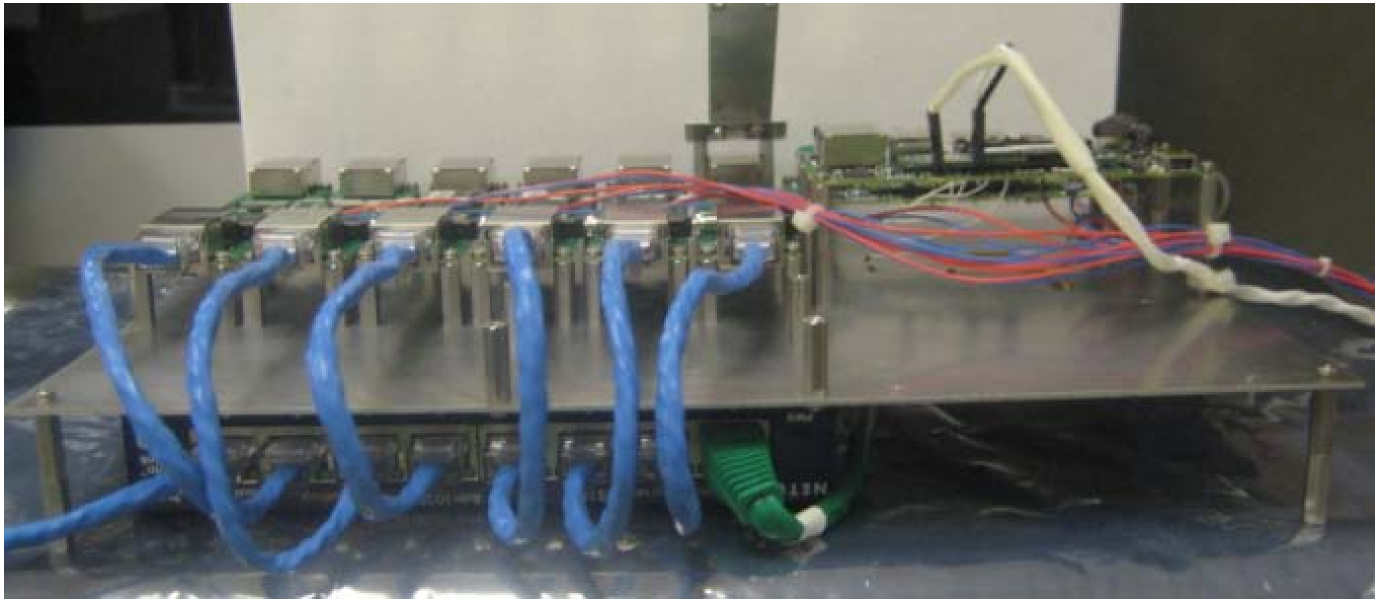
Both the switched +5 volt DC power and the serial command and telemetry interfaces will be demonstrated as part of the Phase 2 Demo

SMDC TechSat DM Phase 2 Breadboard – Stage 1



SMDC TechSat DM Phase 2 Breadboard - Side View





DM Phase 2 Breadboard – Stage 2

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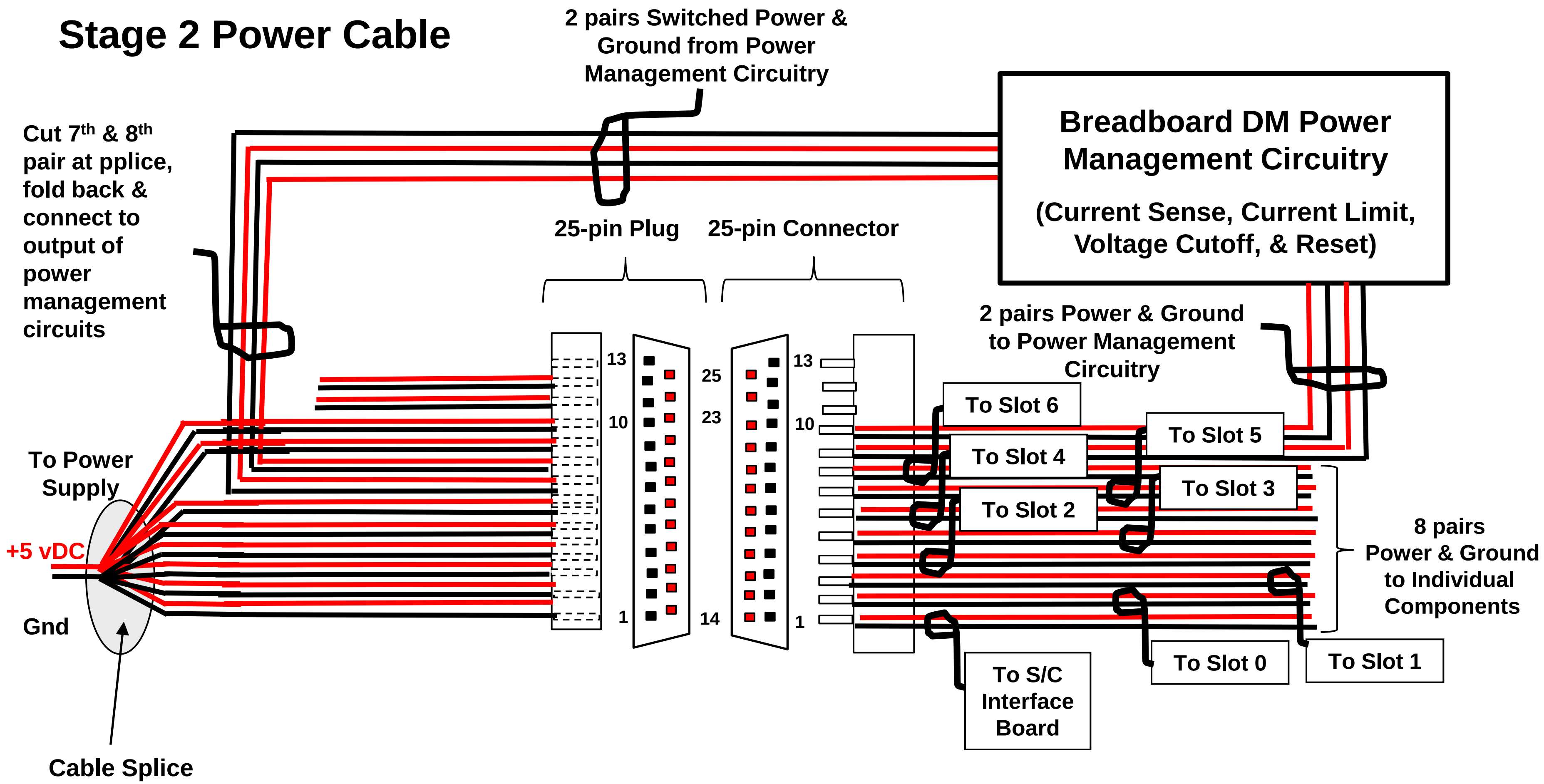
Stage 2 Power Cable



SMDC TechSat Flight Experiment Configuration

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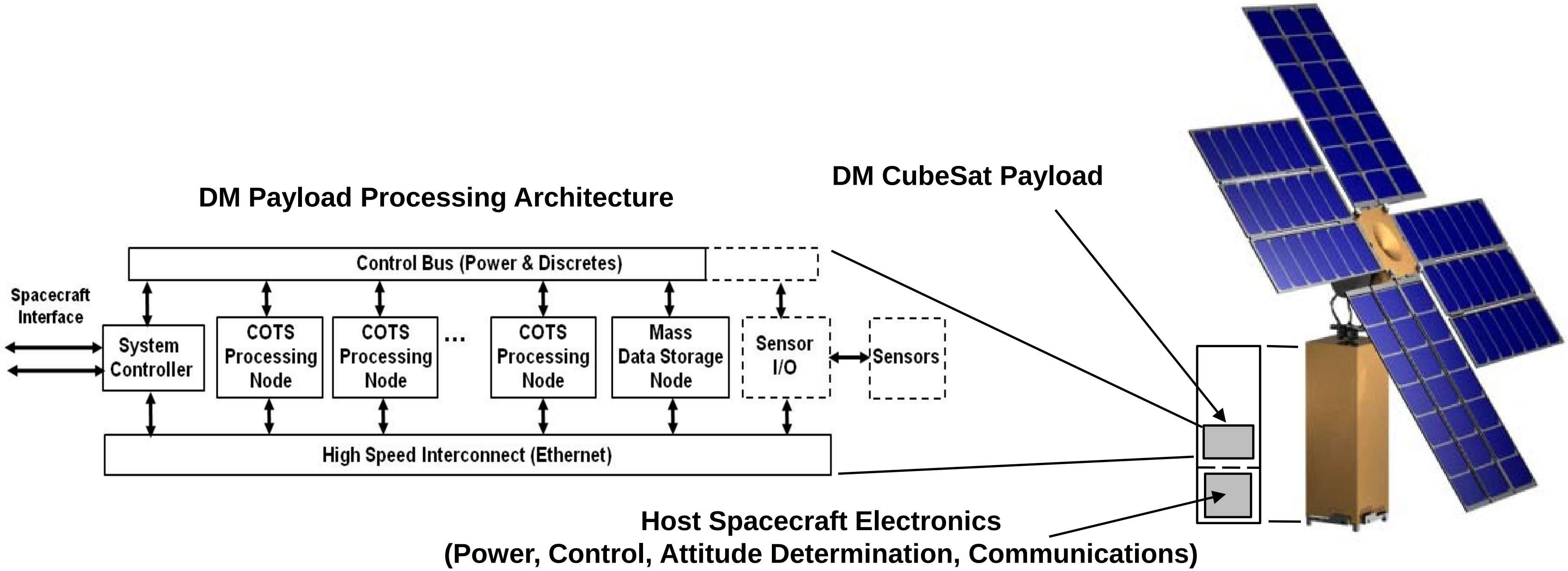

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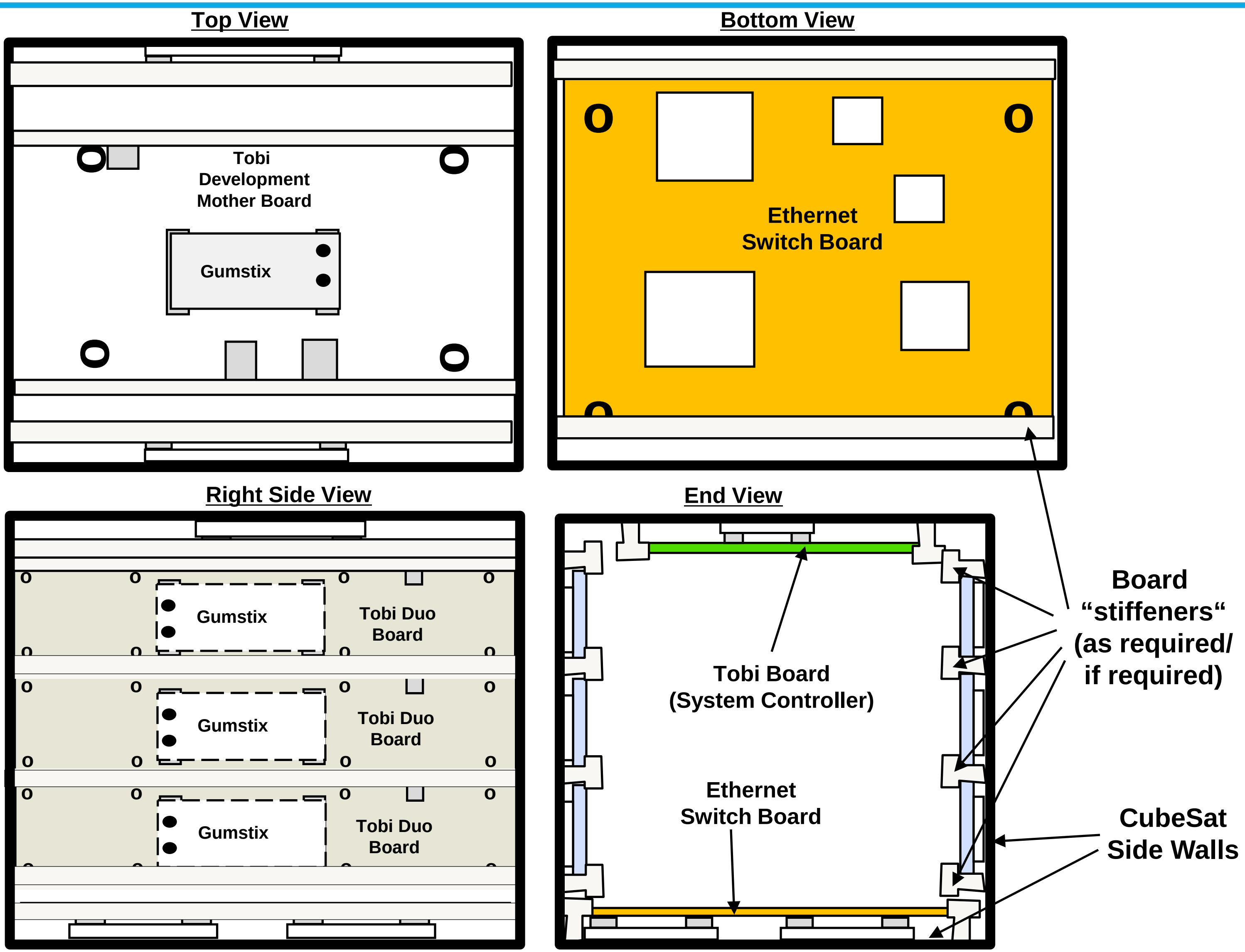
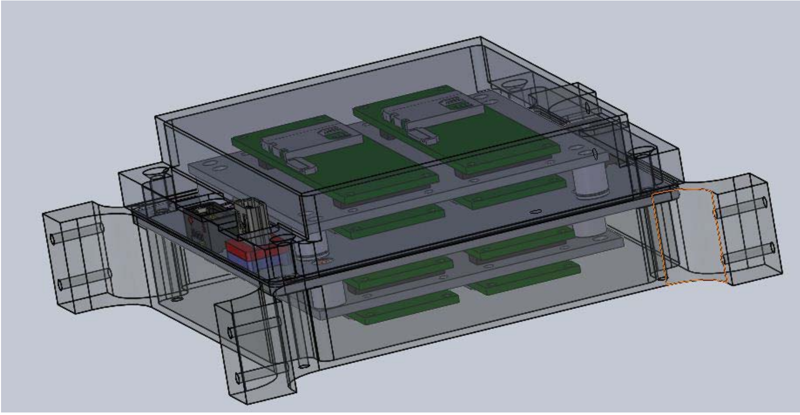
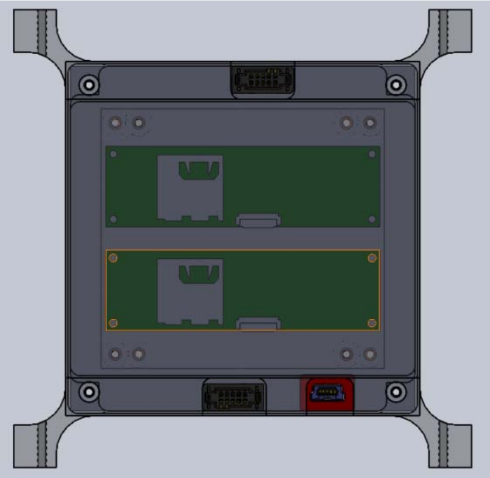


Innovative, clever, doable, but less practical for re-use in future CubeSat applications

DM Subsystem Flight Experiment Implementation

- 75 mm x 75 mm x 35 mm
- Leg extensions to structure
- 8 x DM Processor Modules
- 1 x Ethernet Switch
- DM Current Sense/Current Limit/ Voltage Cutoff/Reset Power Management Circuitry
- USB Port
- Power Port
- Ethernet Port
- JTAG Port
- Room for 100 Pins of Interfaces (GPIO, SPI, I2C, UART, Camera, Etc)





Design is scalable and re-usable in future CubeSat applications

Figures courtesy of Morehead State University

Summary & Conclusion (1 of 2)

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DM Payload Is A Low Risk Experiment Onboard Processing Solution

- Leveraging $14M of NASA NMP ST8 DM technology development through TRL6 technology validation and preparation for a TRL7 flight experiment
- Leveraging Honeywell-funded development of DM CubeSat technology
- DM and DM CubeSat technology is moving closer to flight
- Significant risk reduction already completed

-- preliminary radiation testing performed

-- built a DM CubeSat testbed

--- demonstrated complete DM end-to-end space-ground command and telemetry over RF link

-- successful integration and demonstration of DM payload processing technology as part of SMDC TechSat Flat-Sat demonstration system

--- DM powered from PMAD board

--- DM end-to-end ground & telemetry through C&DH board & SMDC TechSat ground station

--- used existing ST8 DM software including DMM, spacecraft interface, and ground command and telemetry software

-- F-Cubed flight prototype will be demonstrated during SMDC TechSat Phase 2 Demo at Morehead State University on 9/12/12 *

*** If anyone is interested in attending the Phase 2 Demo on 9/12/12, talk to Ben Malphrus or John Samson**

Summary & Conclusion (2 of 2)

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- DM technology benefits
  - DMM is technology-, platform-, and application-independent
  - allows space applications to use state-of-the-art COTS processors
    - -- onboard processing no longer need to be 2-3 generations behind state-of-the-art terrestrial processors
  - applicable to a wide-range of missions
  - allows more onboard processing within a given size, weight, power, and cost constraints
  - supports more science/more autonomy
  - offers faster onboard processing, faster frame processing
  - reduces downlink bandwidth requirements
  - provides processed data/information directly to the user
- Combination of small, light-weight, low-power, high performance COTS processing with high-power CubeSat technology has been indentified as the next key CubeSat development
- The combination of a high power CubeSat & self-healing high performance onboard payload processing meets a critical need for the DoD
- NASA, SMDC, the DM project, and Honeywell are interested in exploring collaborative CubeSat, Small Satellite, UAV, UAS, and HAA flight opportunities

Acknowledgements

Honeywell

- The Dependable Multiprocessor * effort was funded under NASA NMP ST8 contract NMO-710209
- The DM CubeSat effort to date has been carried out on Honeywell internal investment
- The successful SMDC TechSat Flat-Sat Demo was supported by Radiance Technologies, Inc., Morehead State University, and Tethers Unlimited, Inc.
- SMDC TechSat Phase 2 effort is being funded by SMDC under Honeywell subcontract 2011-12-164-001 to MSU

For more information contact:

Dr. John R. Samson, Jr.
Honeywell Defense & Space,
Clearwater, FL
john.r.samson@honeywell.com
(727) 539 – 2449

* The Dependable Multiprocessor (DM) project was originally known as the Environmentally-Adaptive Fault-Tolerant Computer (EAFTC) project

Recent References

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[1] Samson, Jr., John R., "Update on Dependable Multiprocessor CubeSat Technology Development," Proceedings of the 2012 IEEE Aerospace Conference, Big Sky, MT, March 5, 2012.

[2] Samson, Jr., John R., "Implementation of a Dependable Multiprocessor CubeSat," Proceedings of the 2011 IEEE Aerospace Conference, Big Sky, MT, March 8, 2011.

[3] Samson, Jr., John R., "Dependable Multiprocessor (DM) CubeSat Implementation," 2010 Summer CubeSat Workshop, August 8, 2010.

[4] Samson, Jr., John R., Grobelny, Eric M., Clark, M., Driesse-Bunn, S., Van Portfliet, S., "NMP ST8 Dependable Multiprocessor: Technology and Technology Validation Overview," Proceedings of the 48th AIAA Aerospace Sciences Meeting Conference, Orlando, FL, January 4-8, 2010.

[5] Grobelny, Eric M., Samson, J., Clark, M., Driesse-Bunn, S., Van Portfliet, S., "NMP ST8 Dependable Multiprocessor: Technology Validation Approach and Results," Proceedings of the 48th AIAA Aerospace Sciences Meeting Conference, Orlando, FL, January 4-8, 2010.

[6] Samson, Jr., John R., Grobelny, Eric M., Driesse-Bunn, S., Clark, M., Van Portfliet, S., "Post-TRL6 Dependable Multiprocessor Technology Developments," Proceedings of the 2010 IEEE Aerospace Conference, Big Sky, MT, March 7-12, 2010.

[7] Samson, Jr., John R., and Grobelny, E., "NMP ST8 Dependable Multiprocessor: TRL6 Validation – Preliminary Results," Proceedings of the 2009 IEEE Aerospace Conference, Big Sky, MT, March 8-13, 2009.

Track 7 - Spacecraft Avionics Systems, Subsystems, and Technologies at the 2013 IEEE Aerospace Conference (March 2013, Big Sky, MN) has a popular session, 7.04 - Avionics Technologies for Small Satellites, Nano-Satellites, and CubeSats

Back-up Charts

DMM Top-Level Software Layers

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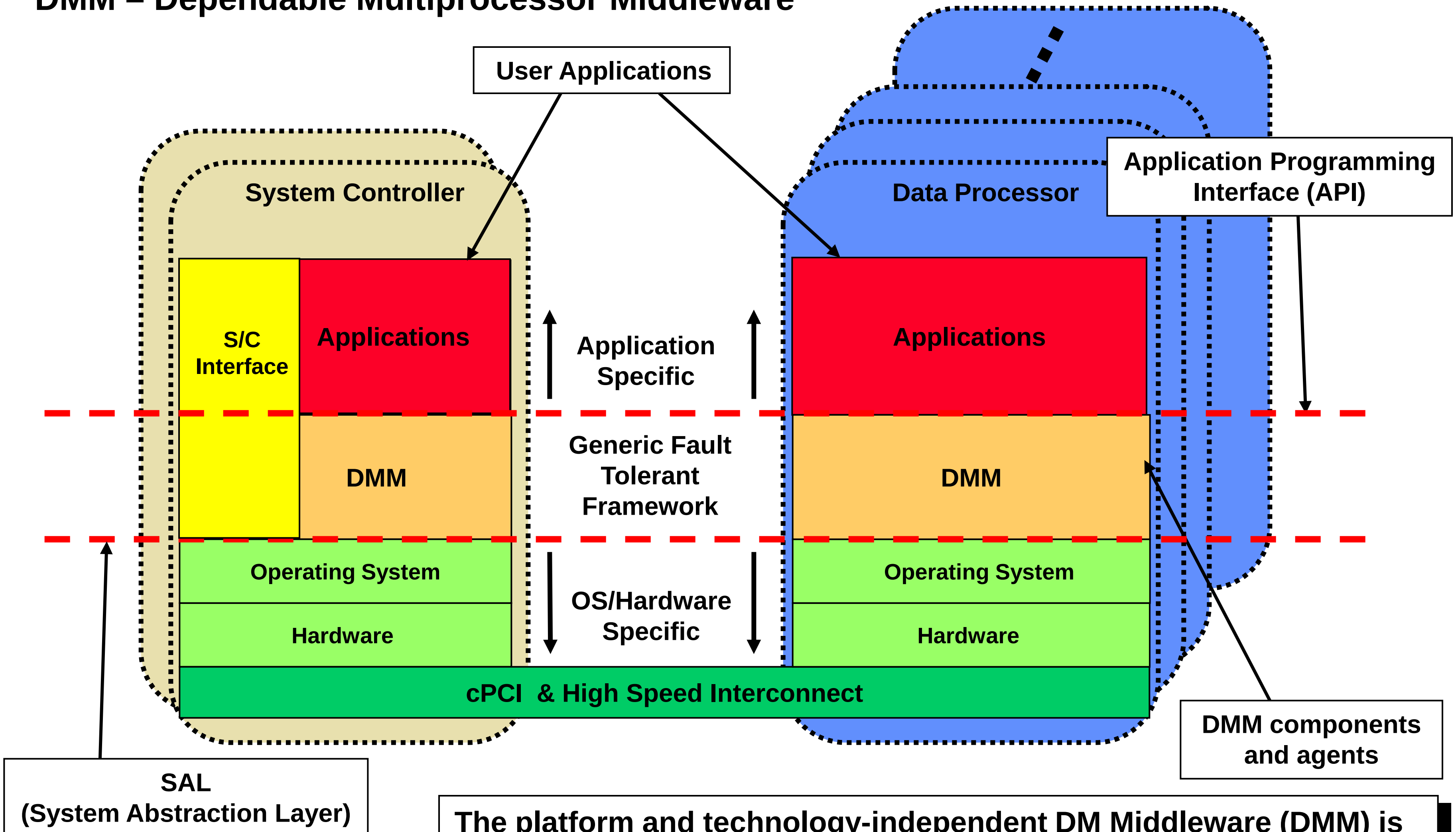
DMM – Dependable Multiprocessor Middleware



The platform and technology-independent DM Middleware (DMM) is DM technology; DM technology is not the underlying hardware

Non-Intrusive DM Flight Experiment

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Notes:
1) DM System Controller could also serve as experiment host computer and/or spacecraft bus controller
2) DM can support multiple sensor experiments on a single flight